Claims

1. A method of altering the refractive index of a region of a crystal comprising focusing a pulsed laser beam at a desired position within the crystal and moving the focused beam along a path such that the focused beam alters the refractive index of the region of the crystal along the path.

2. A method according to claim 1 in which the refractive index of the region is increased.

3. A method according to claim 1 or 2 in which the altered region of the crystal comprises a waveguide.

4. A method according to claim 1, 2 or 3 comprising the steps of moving the focused beam along multiple paths to create a diffraction grating within the crystal.

5. A method according to claim 1, 2 or 3 comprising the steps of moving the focused beam to create a selective reflector within the crystal.

6. A method according to any preceding claim in which at least part of the region of altered refractive index is created remote from the surfaces of the crystal, preferably at a distance of more than 10 μm.

7 A method according to claim 6 wherein the region is created at variable depth from the surfaces of the crystal and preferably forms a three dimensional light guiding structure within the crystal.

8. A method according to any preceding claim in which the effective refractive index of the region is altered by a predetermined amount and preferably increased with respect to the effective refractive index of the adjacent material.

9. A method according to claim 8 in which the intensity of the light beam is modulated whilst the focused beam is moved modulating the predetermined change to the refractive index which is proportional to the intensity.

10.A method according to any preceding claim in which no laser-induced breakdown of the crystal in the path has occurred.

11. A method according to any preceding claim wherein the crystal on which the laser is focused is a laser crystal suitable for use in producing a laser.

12. A method according to claim 11 in which the laser crystal is YAG, Forsteryte, Vanadate, LiSAF, GSGG or Sapphire .

13. A method according to claim 11 or 12 in which the laser crystal is doped, preferably with a metal.

14. A method according to claim 12 or 13 in which the laser crystal is chromium doped, Titanium doped, Tm, Er, Yb or neodymium doped.

15. A method according to claim 14 in which the laser crystal has additional co-doping.

16. A method according to any of claims 11 to 15 in which the laser crystal contains a number of point defects, preferably a substantial number and/or preferably vacancy defects.

17. A method according to any preceding claim in which multiple regions of altered refractive index are created at multiple different depths within the crystal.

18. A method according to any preceding claim wherein the light beam used is a pulsed laser.

19. A method according to claim 18 wherein the pulsed laser is a femtosecond laser with a pulse duration of below 200 fs and preferably around 120 fs.

20. A method according to claim 18 or 19 wherein the laser is operated at wavelength of between 1.35 μm and 1.57 μm, and preferably 1.5 μm, and/or at a wavelength chosen to minimise linear absorption by the crystal.

21. A method according to any of claims 18 to 20 wherein the laser has a pulse frequency of between 0.5 And 1.5 kHz and preferably around 1 kHz.

22. A method according to any of claims 18 to 21 wherein the laser has a pulse energy of around 0.5mJ.

23. A method according to any preceding claim in which the beam is focused by a microscope objective preferably with a numerical aperture in the range 0.2 to 0.65.

24. A method according to any preceding claim in which the focused beam is moved periodically along the path.

25. A laser cavity at least part of which and preferably all is made by the method of any preceding claim.

26 A crystal comprising an inscribed optical structure wherein the structure has a different refractive index to the rest of the crystal and preferably a higher refractive index.

27. A laser crystal for producing a laser beam comprising the crystal of claim 26.

28.. A laser cavity comprising the crystal of claim 26 or 27.

29. A crystal according to any of claims 26 to 27 in which the crystal is YAG, Forsteryte, Vanadate, LiSAF, GSGG or Sapphire.

30. A crystal according to any of claims 26 to 29 in which crystal is doped with a metal and preferably Chromium, Titanium, Tm, Er, Yb or Neodymium doped.

31. A crystal according to any of claims 26 to 30 in which the crystal has additional doping and preferably with Magnesium or Calcium.

32. A crystal according to any of claims 26 to 31 wherein at least part of the optical structure is remote from the surfaces of the crystal.

33. A crystal according to claim 32 wherein at least part of the optical structure is at a depth of over 10 □m from the surface of the crystal and preferably over 100 μm.

34 . A crystal according to any of claims 26 to 33 wherein the optical structure is surrounded on all sides by non-inscribed crystal of uniform refractive index and forming part of the same lattice.

35. A crystal according to any of claims 26 to 34 wherein the optical structure is three dimensional/ has a variable depth with respect to surfaces of the crystal.

36. A crystal according to any of claims 26 to 35 wherein the optical structure comprises a waveguide.

37. A crystal according to claim 36 wherein the optical structure comprises a mulitcore waveguide having a plurality of coupled single waveguides.

38. A crystal according to claim 37 wherein the multicore waveguide is capable of operating as carrier of a common supermode.

39. A crystal according to claim 37 or 38 wherein the plurality of coupled single waveguides are each separated by less than 5 μm and preferably separated by around 3.5 μm.

40. A crystal according to any of claims 26 to 39 wherein the optical structure comprises a diffraction grating.

41. A crystal according to any of claims 26 to 40 wherein the optical structure comprises a selective reflector.

42. A crystal according to any of claims 26 to 41 wherein the optical structure comprises an optical coupler.

43. A crystal according to any of claims 26 to 42 wherein the optical structure has a lower refractive index than rest of crystal.

44. A crystal according to any of claims 26 to 43 wherein the material of the optical structure is part of the crystal and has not broken down.

45 . A crystal according to any of claim 26 to 44 wherein the optical structures comprises a plurality of tunnel regions which passing above or on the side of each other inside the crystal.

46. A crystal according to any of claims 25 to 45 having an increased quantity of defects throughout the crystal.

47. A crystal according to claim 46 wherein the defects comprise one or more of point defect such as vacancies, interstitial defects and substitutional impurity defects. .

48. Crystal according to claim 46 wherein the defects comprise dislocations.

49. Crystal according to claim 48 wherein concentration of point defects is in the range 10^{18} - 10^{21} cm^{-3}.

50. Crystal according to claim 48 or 49 wherein concentration of dislocations is in the range 10^{7} - 10^{11} cm^{-2}.

51. A method of producing a multicore waveguide, comprising a plurality of coupled single waveguides, in a material, comprising the steps of,
focusing a pulsed laser beam at a desired position within the material and moving the focused beam along a path such that the focussed beam alters the refractive index of the region of the material along the path,
and refocusing a pulsed laser beam at a second desired position within the material and moving the focused beam along a second path separated from the first path such that the focussed beam alters the refractive index of the region of the material along the second path.

52. A method according to claim 51 in which the first and second paths are separated by a substantially constant distance.

53. A method according to claim 51 or 52 wherein the multicore waveguide is capable of operating as carrier of a common supermode.

54. A method according to claim 51, 52 or 53 wherein the plurality of coupled single waveguides are each separated by less than 5 μm and preferably separated by around 3.5 μm.

55. A method according to any of claims 51 to 54 wherein the step of refocusing and creating an additional altered region along an additional path is repeated 10 or preferably 20 times to produce a multicore waveguide comprising 10 or preferably 20 coupled single waveguides

56. A method according to any of claims 51 to 55 wherein the material comprises a crystal.

57. A method of fabricating an optical structure in an active crystal comprising focusing a pulsed laser beam at a desired position within the crystal and moving the focused beam along a path such that the focused beam alters the refractive index of the region of the crystal along the path.

58. A method according claim 1, 51 or 57 in which the average refractive index of the region is decreased.

59. A method according to claim 58 wherein the refractive index of the region is increased in part and decreased in other parts.

60. A laser formed by a waveguide inscribed in a crystal of YAG lodged with Nd^{3+}

61. A laser according to claim 60 and 36 or 37 and having feedback elements.

62. A laser formed by an effective waveguide having a cladding of depressed refraction index, preferably where the core of unmodified material is surrounded, at least in part, by a number of tracks comprising material modified in a way to mainly decrease the refractive index.